Persistent Exploitation of Persistent Sensing

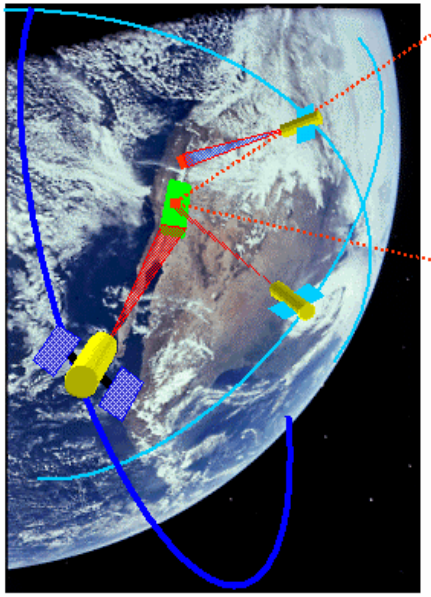
September 2005

Thomas M. Strat
Program Manager

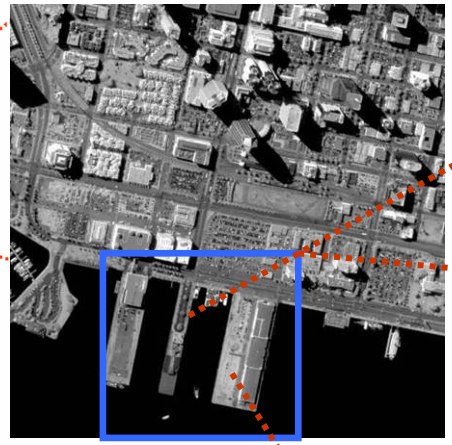
Exploitation of Persistently Sensed Imagery

For the first time in history we are data-rich. Can this paradigm shift be exploited to break through to a new level of capability?

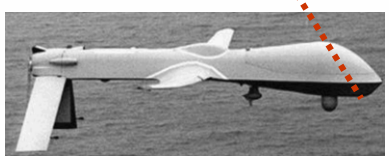
Continuous Data Collection

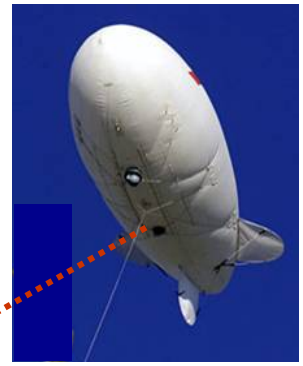


Satellite imagery



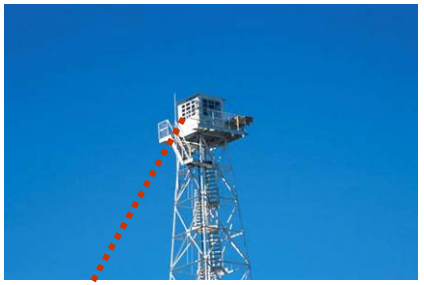
Imagery courtesy of Space Imaging Inc

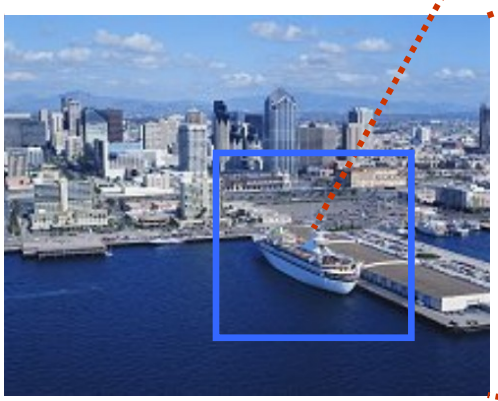




Aerial Sensors

Ground-based Sensors





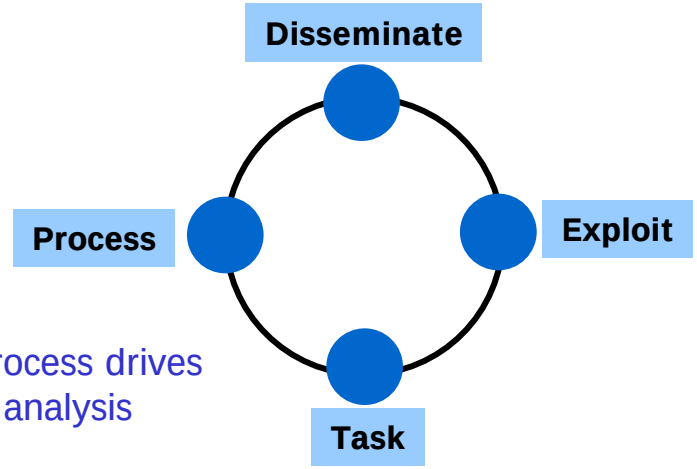
Given persistent surveillance, what can be automated?

- Persistent tracking vs broad area search
- Continuous monitoring vs periodic change detection

The Exploitation Problem

Classical IMINT: designed for the cold war

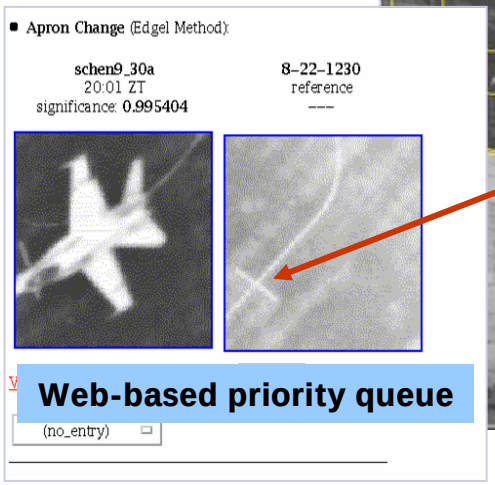
- Fixed facilities
- Standard intelligence elements
  - Force level
  - State of readiness
  - Infrastructure
- Strategic issues
  - Weapon testing
  - Trans-shipment



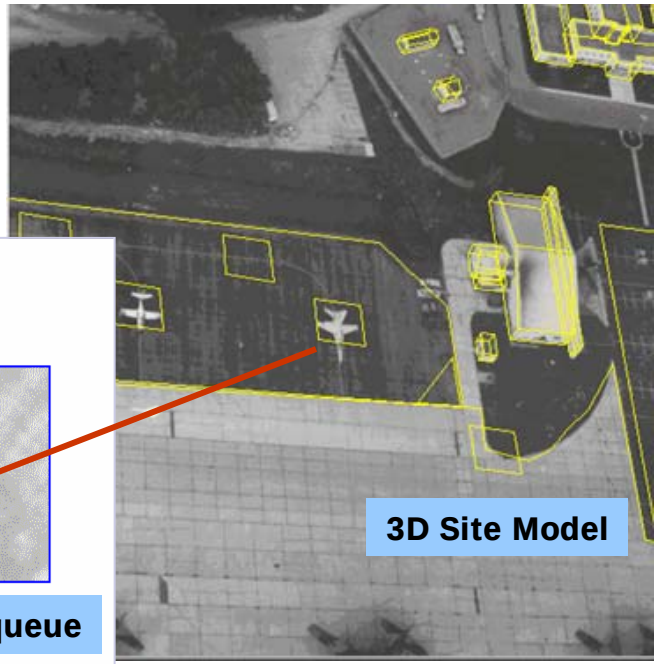
The "TPED" process drives collection and analysis

Typical Facility

Operational Testing:
90% accuracy
5% False Alarms



Web-based priority queue



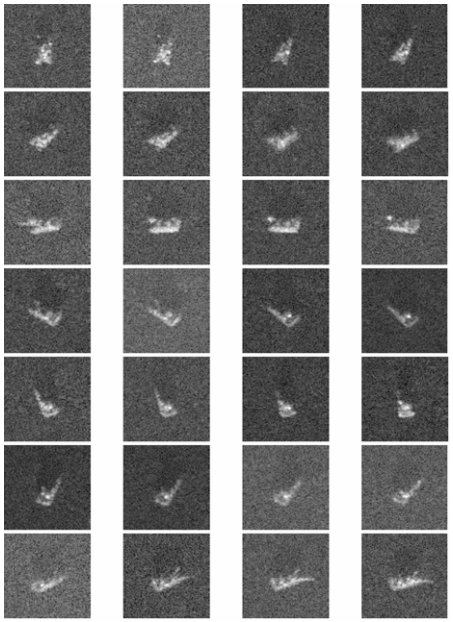
3D Site Model

ATR: designed for conventional warfare

T72

M109

M110

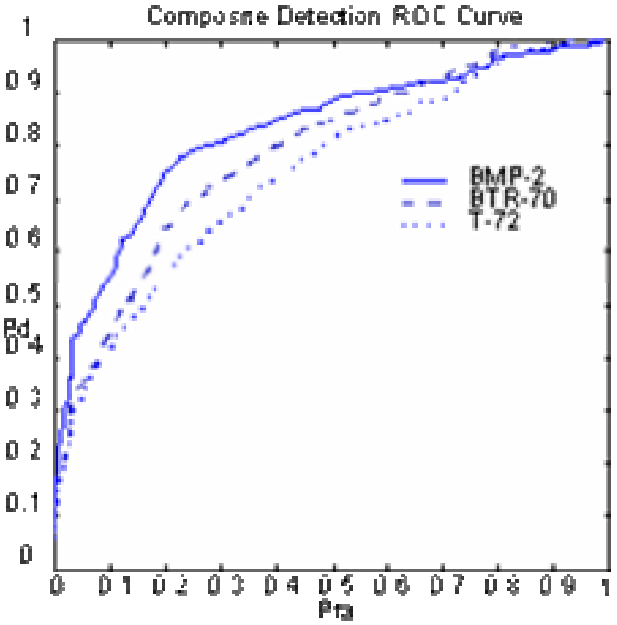


T72 Tank SAR signatures under various poses

ATR systems have emphasized SAR and FLIR, some experience with LIDAR and EO.

BMP2

BTR70

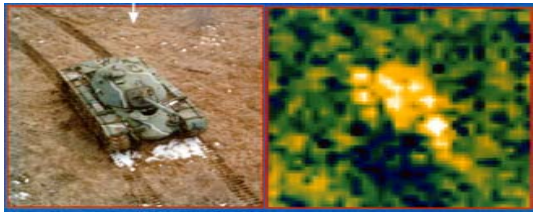


MSTAR Evaluation
Velten et al, 1998

New models can be generated from high-resolution ground-level imagery, but through manual interaction, e.g. days-weeks per model.

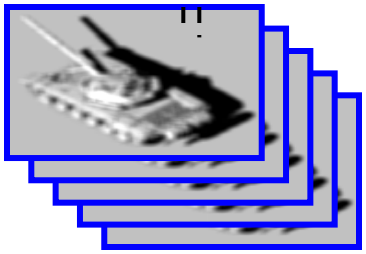
Why Is ATR Difficult?

2D projection of a 3D world



Self-shadowing

Indexing problem



Complete object not visible

Models vs specific instances

Appearance varies

Camouflage, Concealment, & Deception

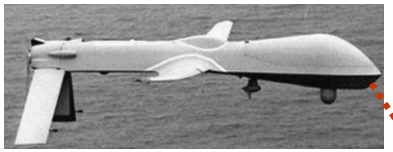
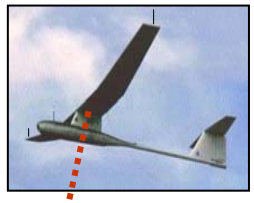
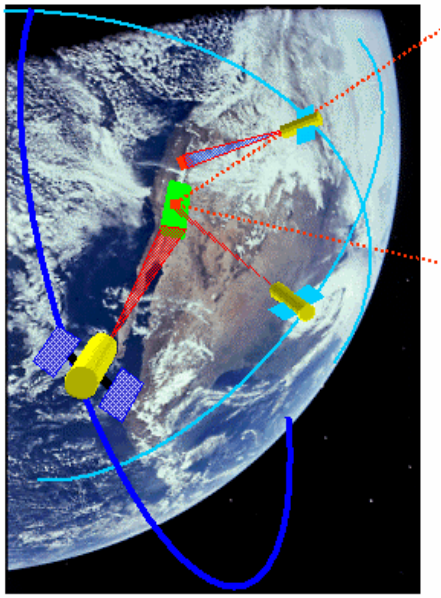
Donkey-Powered Mortar Launcher

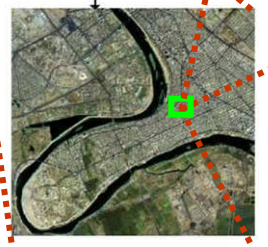
Persistent sensing offers a new way forward

- A constellation of sensors
- All spatial scales
- All fields of regard

Any Country
Any Region
Any City
Any Street
24x7

For the first time in the history of image understanding technology, we are data-rich. Can this paradigm shift be exploited to breakthrough to a new level of capability?




Persistent sensing enablers

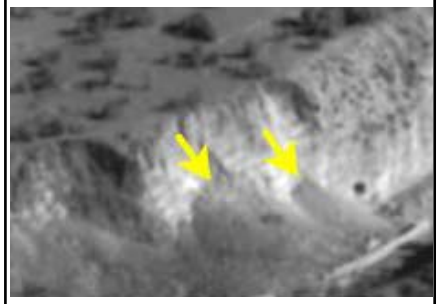
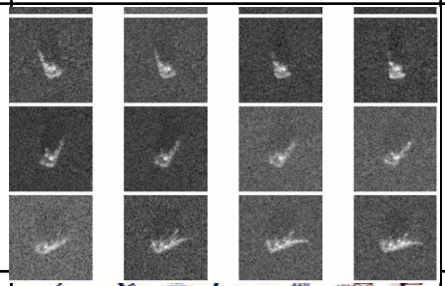
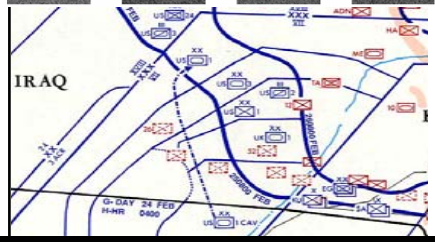
- Calibration – Do it once! Slowly adapt with changes to the environment
- Continuity - The correspondence problem is minimized due to small viewpoint changes from frame to frame.
- Redundancy – The same object is imaged hundreds of times with slowly varying viewpoint and illumination.
- Detection – Moving objects are easily segmented from the background.
- Identity – Tracking an object confirms that it has the same identity so recognition can adapt.
- Learning – Rich collections of observations enable algorithms that learn through experience

PEPS Challenges

Definitions: Categories of Observations

- Site-Oriented Observation:
  - Detecting, understanding, and characterizing activity and classes of activity and related functions tied to a specific geo-spatial location
- Event-Oriented Observation:
  - Finding and characterizing events or patterns of activity occurring independently of a specific geo-spatial location and recognize significant changes in activity or new types of activity or events
- Vehicle-Oriented Observation:
  - Detecting, recognizing and characterizing ground vehicles and classes of ground vehicles based on their appearance and behavior
- People-Oriented Observation:
  - Detecting, tracking, and characterizing people and their behavior individually and in groups

Exploitation Evolution

Focus	Today's Capability		Future Vision	
Site Centric	Detect changes at fixed locations by comparing observations separated by days or weeks		Persistent observation and detection of activities and patterns as they unfold; monitor and understand what's happening	
Event Centric	Search for small-scale changes in lightly trafficked areas or detect large-scale, long-term physical changes over wide areas.		Recognize significant changes and dynamic events by observing and modeling ongoing normal activity and events in urban areas. Relate events at separate locations.	
Vehicle Centric	Recognize military vehicles from among a small number of highly standardized types		Recognize improvised military vehicles: civilian and commercial vehicles adapted to military or terrorist use	
People Centric	Detect and characterize ground order of battle for motorized forces		Detect & discriminate insurgents and dismounted combatants from non-combatants	

PEPS
Research Infrastructure

Innovation

- Innovation is needed to address the many challenges facing NGA
- Much innovation comes from academia and unclassified research laboratories
  - We need to get academics and uncleared researchers involved
    - Most NGA data is classified
    - NGA prototype systems are ITAR restricted
    - Many professors and students are not US citizens
    - Use of simulated data doesn't work

What can we do?

Continuous Data Feeds

Dedicated Data Collection Site

Government or Contractor Site

Secure Perimeter

Unclassified, non-ITAR, non-OPSEC-sensitive

AF Medical Squadron

Collection Area Subset of Site

USAF School of Aerospace Medicine

Rich activity and events

Explicitly Address Privacy Issues

- Privacy addressed upfront & ongoing basis
  - Process for site selection
  - Explicit privacy policy
  - Monitor compliance
- Opt-in participation
  - Restricted access to site, already monitored
- No personally identifying data
- Area internal to larger secured site
  - No potential for criminal benefit from data

Continuous Collection, Open, Ongoing Dissemination

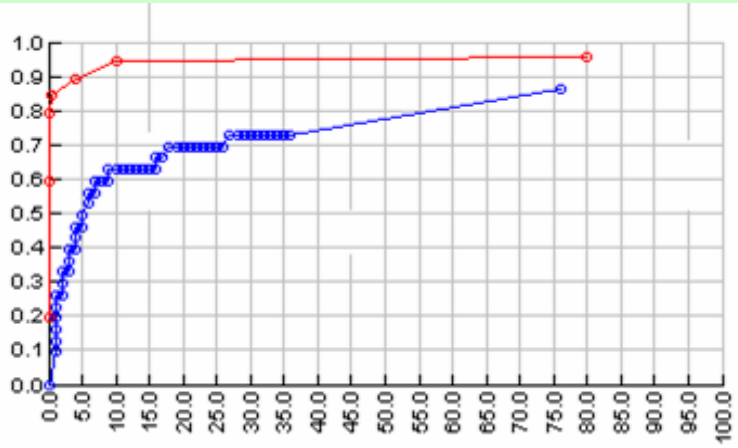
Exploit Analogous Challenge Problems

- Detect IED installation → Detect road construction
  - Pd, FAR
- Classify targets → Recognize tow trucks, police cars
  - Confusion matrix
- Persistent tracking → Track taxis, joggers
  - Expected track length
- Discriminate noncombatants → Discriminate messenger, policeman, executive, visitor
  - Confusion matrix

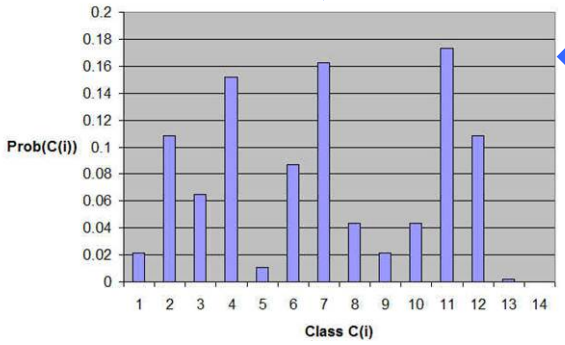
Seek solutions to these (and other) challenge problems

Continuous Evaluation

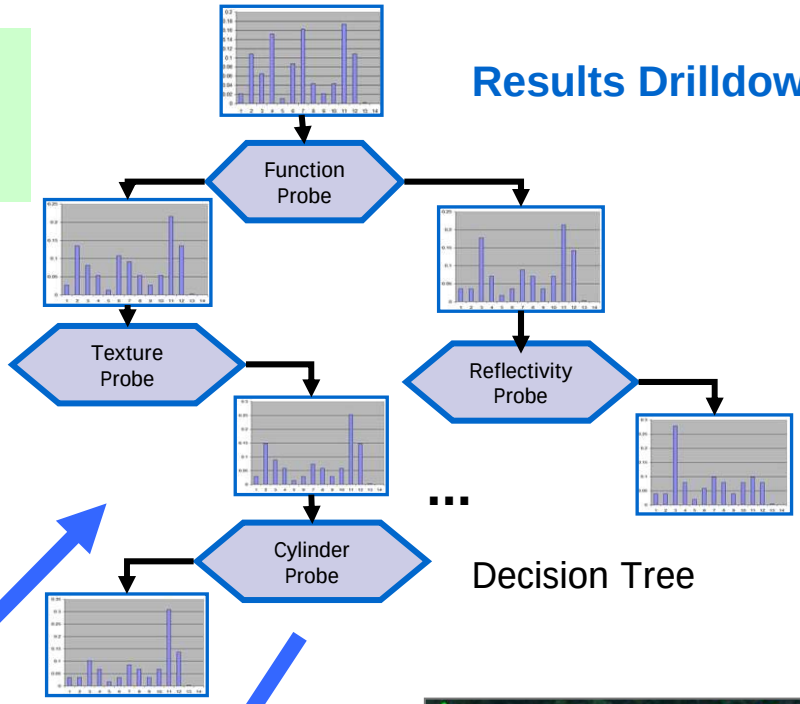
- Algorithms and data sets available via Web
- Open to all
- Challenges other labs to surpass



Receiver Operator Characteristics

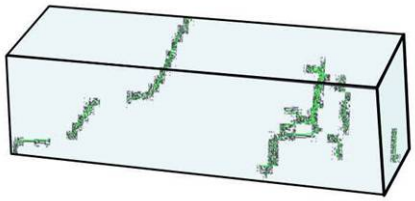


Class Probability



Results Drilldown

Decision Tree



3-d Features

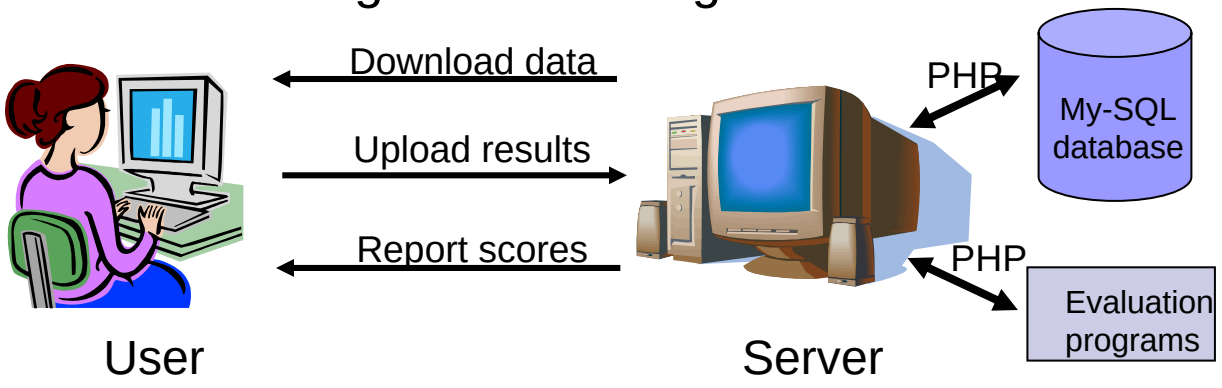
2-d Features

VIVID Airborne Tracking Evaluation Web Site

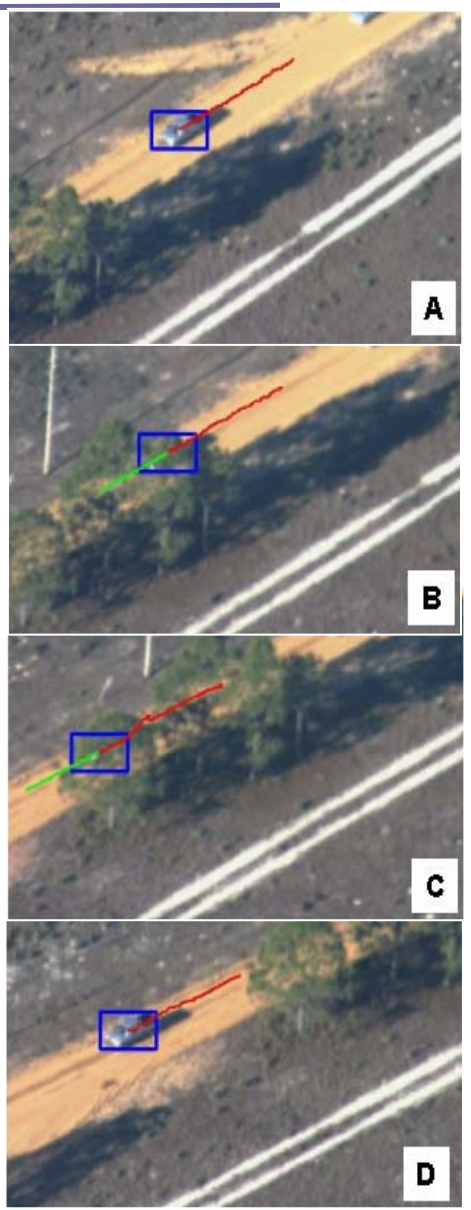
The goal: enable third party self-evaluation of tracking algorithms on airborne video data.

Web site highlights

- ground truth tracking datasets for download
- open source testbed with baseline algorithms
- upload of user-generated tracking results
- on-line, automated scoring mechanism
- table of algorithm rankings with citations



www.vividevaluation.ri.cmu.edu



PEPS

- **Persistent Surveillance**
  - Automation is necessary
    - Too much data, not enough eyeballs
  - Current exploitation tools are inadequate
    - ATR is ineffective, TCTs remain elusive, urban problems
  - Data-rich environment makes automation easier
- **Innovation is needed**
  - Most innovation comes from academia, not defense contractors
- **Research must be data-driven**
  - ISR data is classified (or at least export-controlled)
  - Use of simulated data is ineffective
- **Establish a data collection site**
  - Oversight process to assure privacy
  - Variety of sensors
  - Live dissemination via web
- **Focus research on challenge problems**
  - Continuous evaluation